



## Short Communication

### Instrumentation system for parametric data collection of OTEC using deep sea moored surface buoy

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Ocean Thermal Energy Conversion (OTEC) is a clean form of ocean energy and one of the best sources for the mitigation of electrical power demand in islands in the vicinity of tropical countries like India. An integrated ocean observatory system has been developed by the National Institute of Ocean Technology (NIOT) for the design of OTEC plants. The system comprises of a surface buoy anchored in 1200 m water depth. Sub-sea sensors are mounted on the induction mooring cable to enable reading and transmission of the water temperature, water velocity and other in-situ data on a real-time basis. This paper explains the unique oceanographic instrumentation system developed and implemented for the deep-sea moored surface buoy system at Kavaratti, Lakshadweep. The data received is logged onto an onboard Data Acquisition (DAQ) system and communicated through wireless mode Internet of Things (IoT) and redundant communication system using a Radio Frequency (RF) antenna. This DAQ system can handle high sample rates and large-size data packets without any interruption. The system architecture is designed with several modes of communication to ensure loss free data collection. This specially designed deep-sea moored observatory system can be implemented for similar oceanographic observations. The oceanographic profile data of water temperature, depth, and water velocity received from the system would be helpful in designing OTEC plants.

[**Keywords:** Data buoy, IoT Ocean energy, Offshore instrumentation system, OTEC]

### Introduction

India, being a tropical country, possesses huge potential for OTEC resources<sup>1</sup>. With sufficient availability of ocean thermal gradients in India, there are large possibilities to generate electricity from OTEC as a renewable energy source. The demand for power and freshwater in tropical islands have been increasing due to population growth, climate change, etc. A deep-sea moored surface buoy observatory system has been designed and deployed to ensure

availability of adequate thermal gradient at the OTEC site. This observatory system helps measurement of the parameters such as water temperature, water speed or water velocity, water direction, and water depth from each sensor mounted on an induction cable at desired locations up to a depth of 1000 m. The entire system has been designed to withstand offshore harsh environments. Literature survey found the OMNI (Ocean Moored Buoy Network for Northern Indian Ocean) buoy network comprising 12 buoy systems that measure temperature and salinity profile at discrete levels up to a maximum of 500 m depth<sup>2</sup>. Activities at offshore are always challenging due to the dynamic nature of the oceans. The sensors and associated system components have been chosen to suit the marine environment<sup>3</sup>. Offshore instrumentation, data acquisition, and communication are a major challenges, and, therefore, a state-of-art system has been developed for this purpose<sup>4</sup>. This buoy system has an indigenously developed inductive mooring cable which was manufactured in India and used for the measurement of depth up to 1000 m. This paper focuses on the instrumentation system for data collection and the processing of the obtained data from the deep-sea moored surface buoy observatory system.

### Materials and Methods

The methodology relates to the indigenously designed and developed instrumentation system architecture, which collects data up to a depth of 1000 m. The configuration of the system is shown in Figure 1. The instrumentation system has three subcomponents mentioned below.

- i) Instrumentation system & measurement plan
- ii) Onboard self-sustained power supply system
- iii) IoT based real time data transmission through hybrid communication system RF & Global System for Mobile communication (GSM).

### Instrumentation system and measurement plan

Instrumentation system has been robustly designed to enable withstanding offshore conditions. This design involves a measurement plan, selection of sensors, uninterrupted data acquisition, transmission through multiple platforms, and real-time study of the observed data.

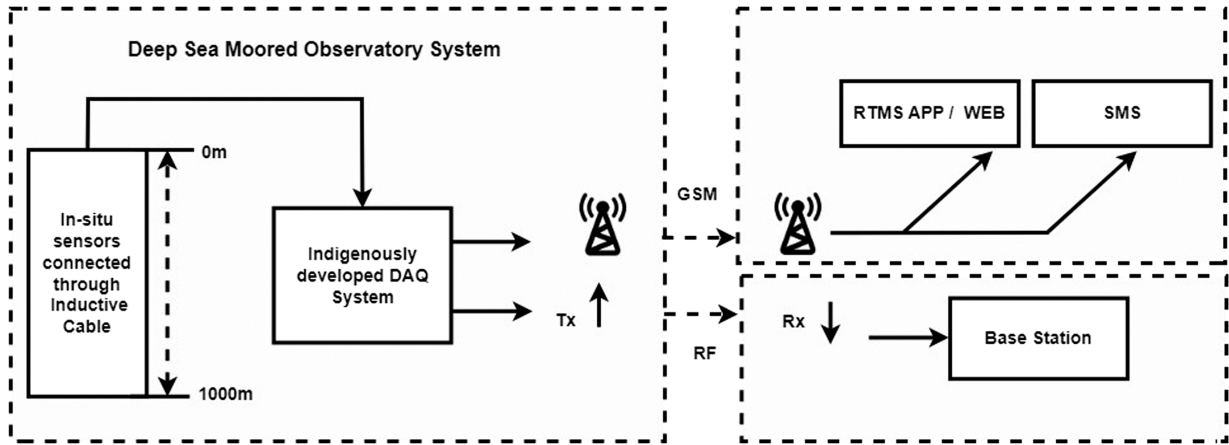


Fig. 1 — Architecture of the buoy real-time data communication system

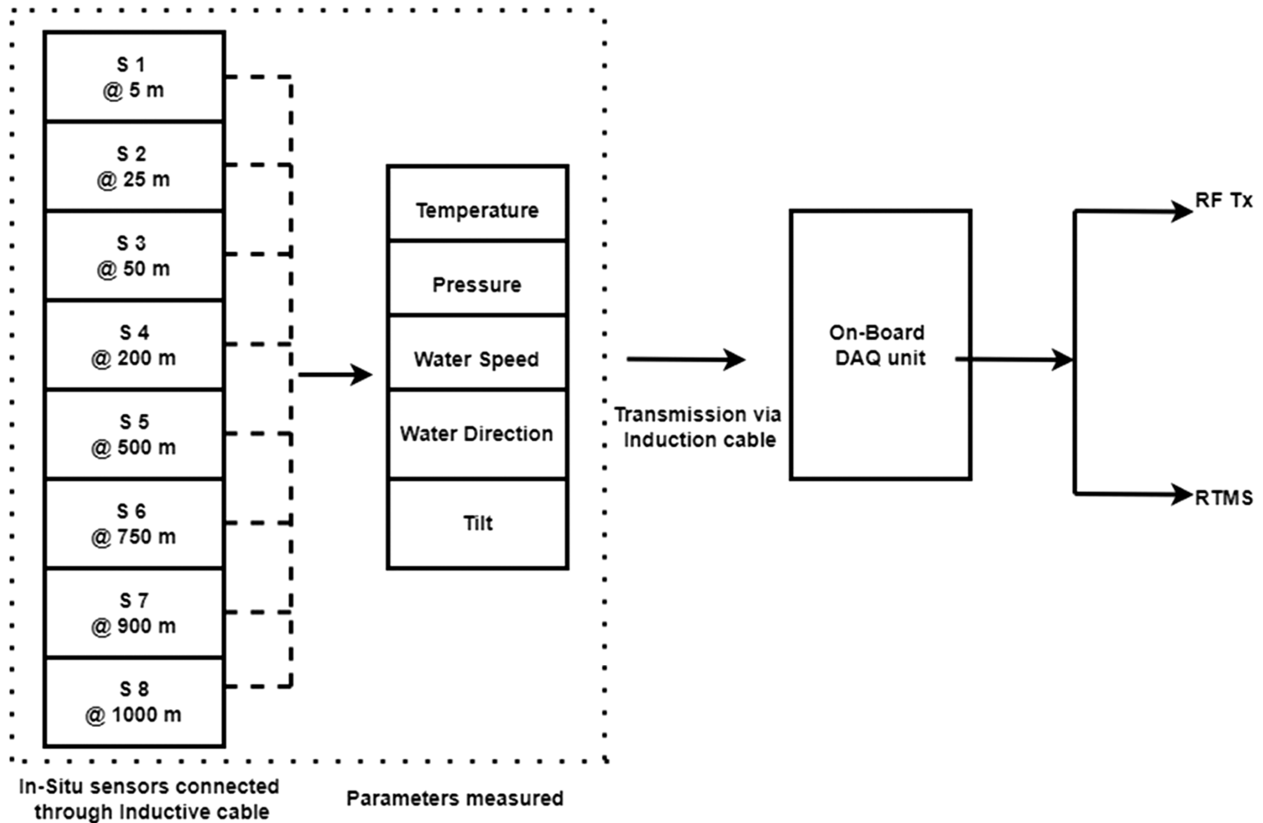


Fig. 2 — Measurement plan for deep sea moored buoy

The data collected by each sensor is transmitted to the DAQ system through the inductive cable, as shown in Figure 2. Besides, the Global Navigation Satellite System (GNSS) or Global Positioning System (GPS) antenna output is fed into a GPS receiver for tracking the buoy position and acquisition of real time buoy position. As a redundancy to monitor the position, Advanced

Research and Global Observation Satellite (ARGOS) positioning system is also installed on the buoy.

The measurement plan shows the typical measurements to be acquired and observed, as stated in Table 1.

Figure 3 shows the detailed integrated assembly of the DAQ unit/data logger, surface inductive modem,

and RF transmitter. The complete system was housed in a stainless-steel watertight enclosure.

#### Onboard self-sustained power backup system

A self-sustained power backup system is essential to meet the estimated power budget of the onboard oceanographic observatory system. The approximate power budget of the system is 6 Wh. The power system consists of two modules of 12V (100 Ah) battery with eight 50 W solar panels installed for meeting this requirement. The total continuous current

consumption of the onboard system is around 0.5 Amps. Figure 4 is the block diagram of a self-sustained power supply system.

#### Real-time data transmission through hybrid communication system (RF&GSM)

Besides local data storage, the wireless communication system with IoT application has been designed and installed onboard. The IoT consists of the following applications: Base station through RF, Real-Time Monitoring System (RTMS) through 4G network (IoT), and Short Message Service (SMS).

The aerial distance between the buoy and the base station is nearly 4 km; as a primary source, remote data collection and transmission were implemented by integrating it with a 4G network-compatible DAQ unit. This buoy was deployed on the off-island, and so there is a probable chance of poor or loss of network. Hence, a secondary source of redundancy,

Table 1 — List of measurements

Parameters to be observed	Range of the measurement	Accuracy of the measurement
Temperature	-4 to +40 °C	0.1 °C
Speed	±5 m/s	±1%
Direction	0° to 360°	2°
Pressure	6000 Bar	0.5%

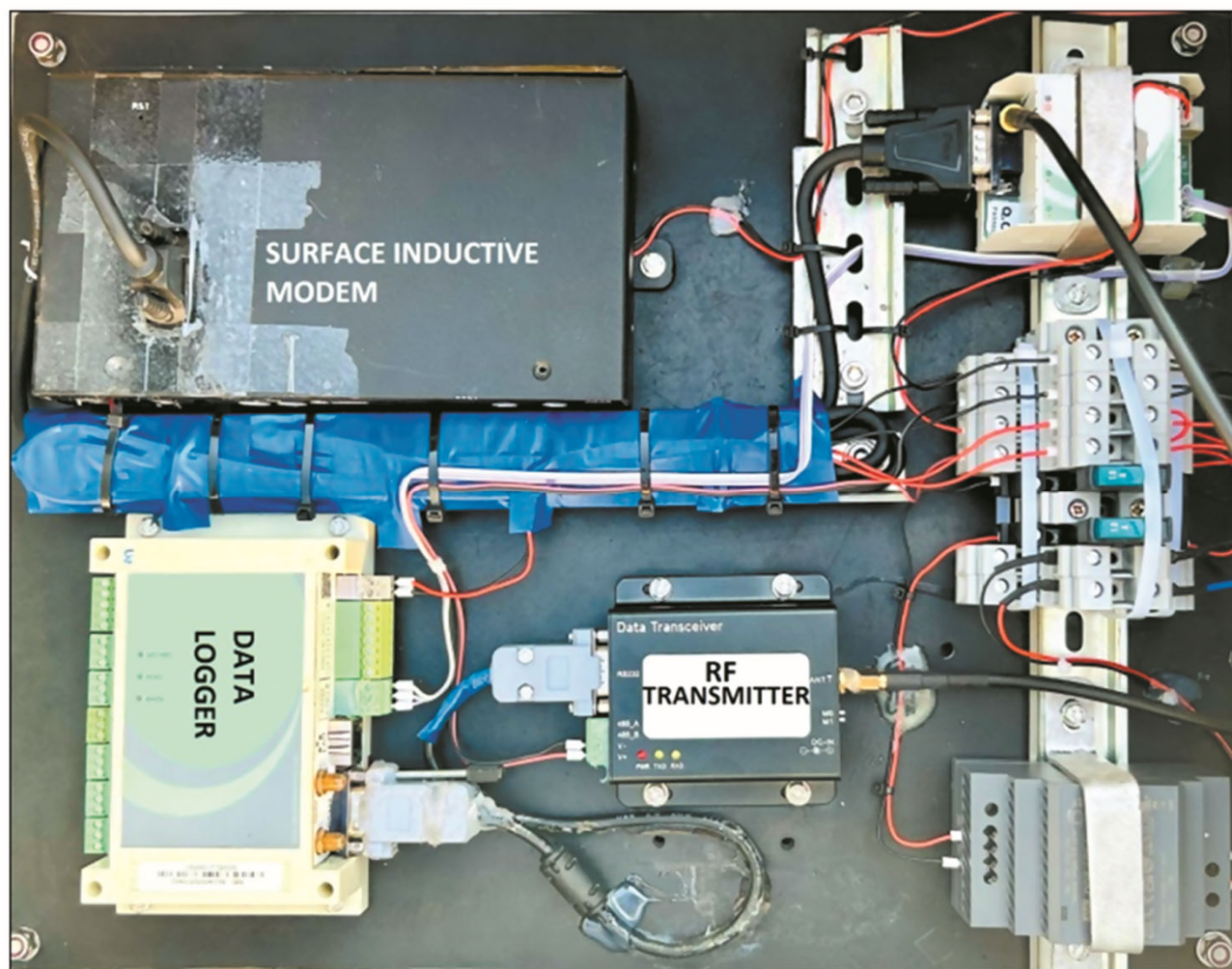


Fig. 3 — Internal assembly of the DAQ system

omnidirectional antennas with a clear line of sight, were used for the data transmission to the base station. The observatory system is capable of pushing the data of eight numbers of underwater sensors (S1 to S8) at the desired sampling rate to the File Transfer Protocol (FTP) server. The elucidation of RF transmission is shown in Table 2.

Figure 5 shows the real-time data such as water temperature, depth, battery voltage and location that can be viewed in the RTMS mobile application on real-time basis. This data is transmitted through the IoT application.

**Data analysis and processing**

The deep-sea observatory buoy deployed in the location shown in Figure 6 has been working continuously since deployment for more than a year.

The data logged in RTMS over 12 months was processed and analyzed, and the following can be inferred. Figure 7 shows the monthly average variations in temperature along the sub-sea sensors connected at different depths from the surface of the sea 5 m to a depth of 1000 m. Decrease in water temperature following increase in the depth can be seen.

The monthly average variations in water speed along the sub-sea sensors mounted on the underwater mooring cable connected under the floating buoy are shown in Figure 8.

Data representation (rose-plots) of a typical sensor (S2) deployed at 25 m water depth is shown in Figure 9. A change in the direction of water velocity for February 2024 predominately towards the north-west direction can be seen.

The deployment location of the sea surface buoy off the coast of Kavaratti, Lakshadweep, tracked by ARGOS is shown in Figure 10. The buoy movement and watch circle are also shown.

Table 2 — RF transmission system

Specification	Range
Frequency band	865 – 867 MHz
Data rate	19.2 kbps
RF power	30 dBm
Antenna	External
Antenna type	Cylindrical omnidirectional fibre antenna
Antenna gain	12 dB
DC power input	12 VDC
Bit error rate	0.1 %
Baud rate	9600

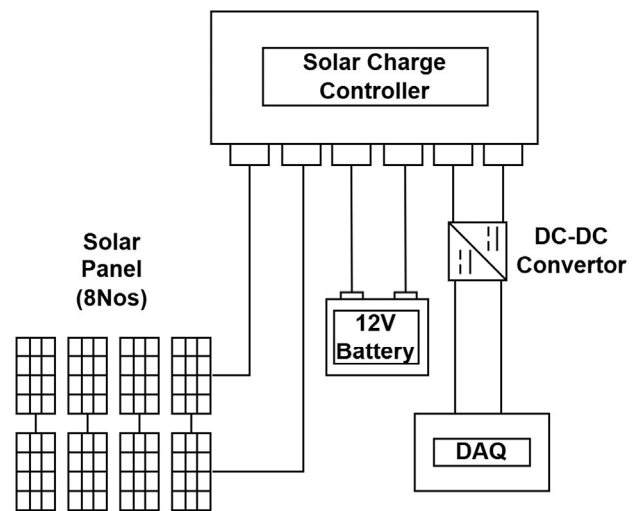


Fig. 4 — Schema of onboard power supply system

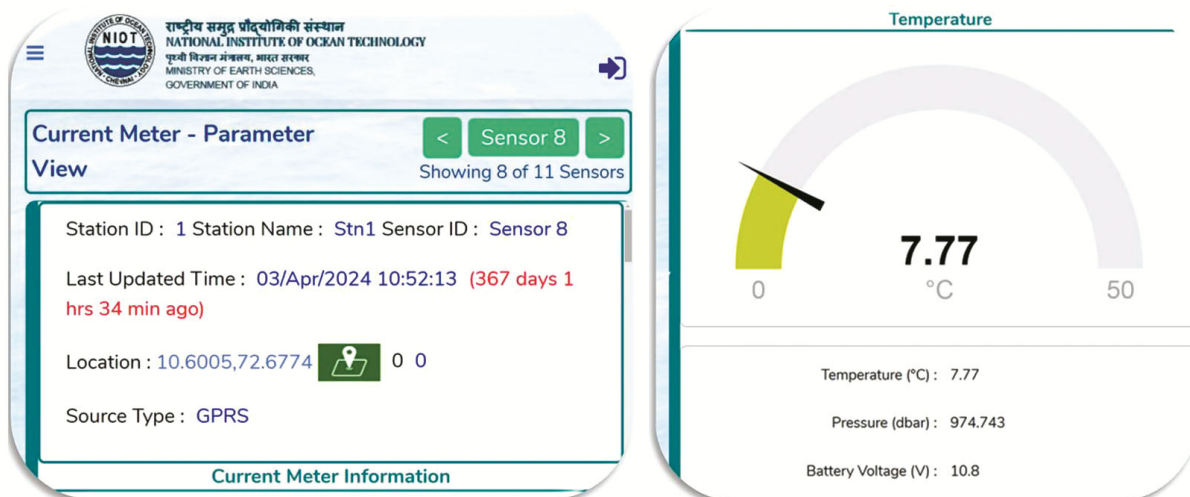


Fig. 5 — Real-time data screenshot from a 1000 m depth in a mobile application



Fig. 6 — Buoy deployed at Kavaratti, Lakshadweep

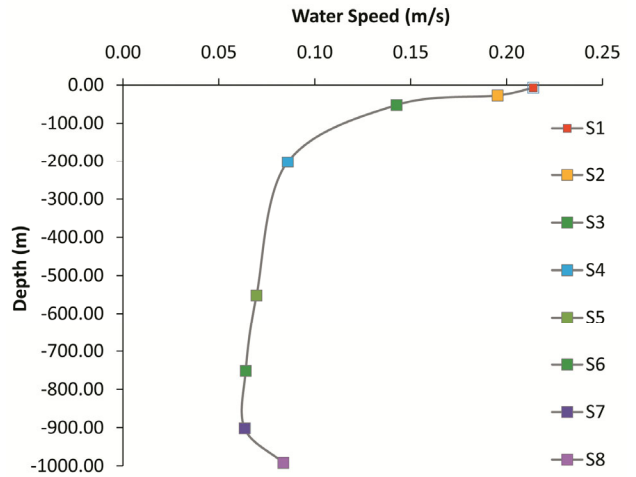


Fig. 8 — Average variation of water speed along the depth

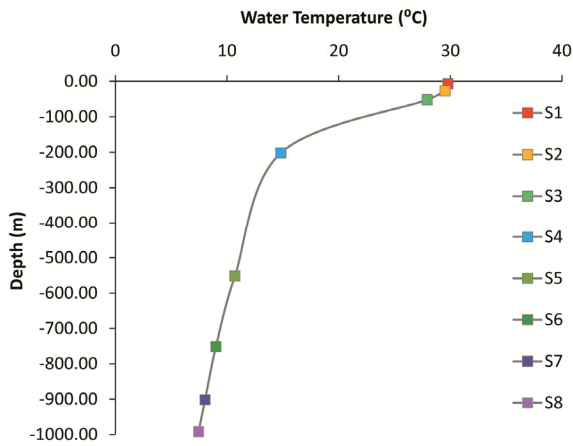


Fig. 7 — Variation of water temperature along the depth

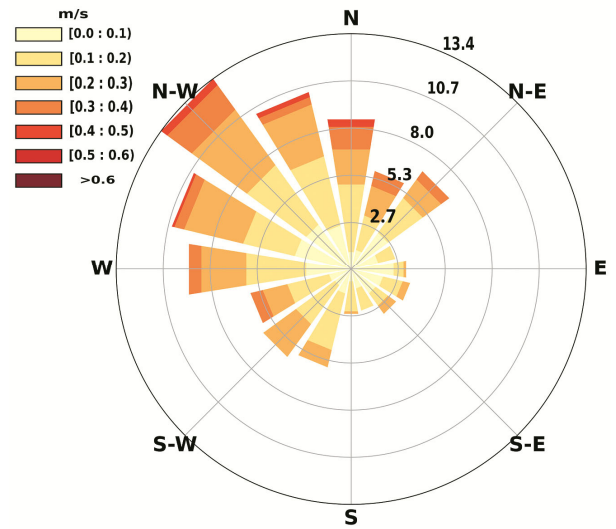


Fig. 9 — Rose-plot showing variation in water velocity direction for S2

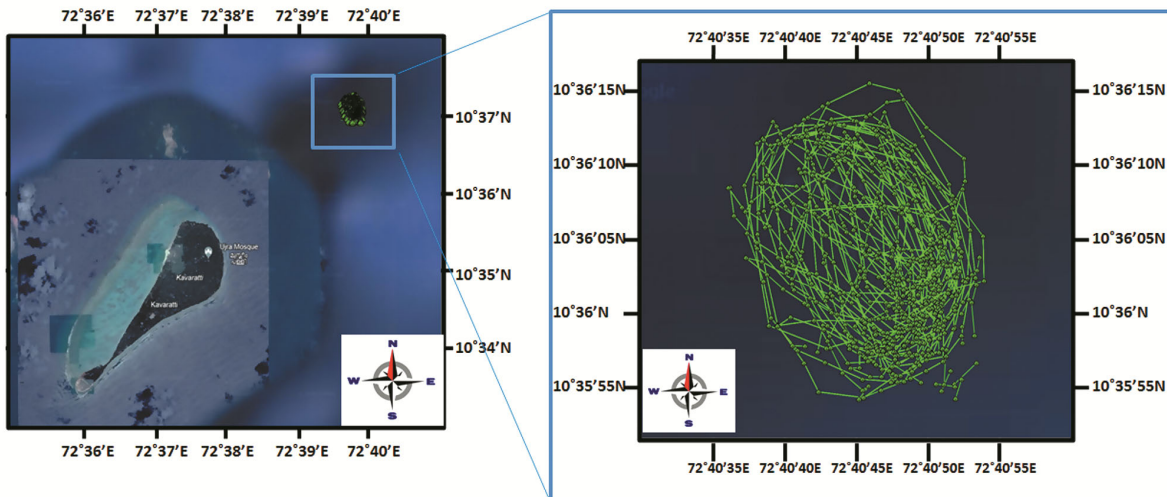


Fig. 10 — Location of the deployed buoy and tracking at Kavaratti, Lakshadweep

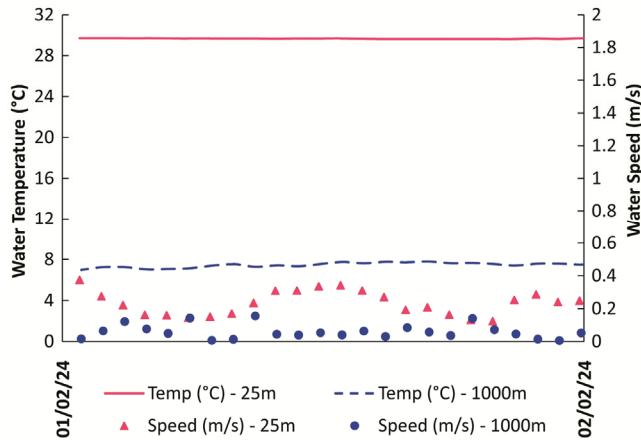


Fig. 11 — Time series plot of S2 (-25 m) and S8 (-1000 m) of a typical day

Figure 11 shows 29 °C as the temperature at 25 m depth (S2) and 7 °C at 1000 m depth (S8). The temperature gradient between the S2 and S8 is seen at ~22 °C. The time series plots have been plotted for hourly data of a typical day (Fig. 11).

### Conclusion

The instrumentation system for deep-sea moored surface buoy was designed, developed and deployed at the OTEC site. The indigenously developed oceanographic observatory instrumentation system has been successfully tested, and data has been collected through various platforms for over a period of a year through use of various modes of communication. The data analysis confirmed availability of sufficient temperature gradient required for the OTEC process. No failure was observed in the instrumentation and communication system during the entire period of observation in the open sea.

### Acknowledgements

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### Conflict of Interest

The authors declare that they have no known competing financial interests that could have appeared to influence the manuscript reported in this paper.

### Ethical Statement

All of the authors have read the manuscript thoroughly and confirm that it has neither been submitted to any other journal and nor been considered for publication. All authors have been actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

### Author Contributions

BP: Planning of the work, manuscript preparation, and writing - original draft; TS, AP & PKSA: Conceptualization, supervision, planning of the work, and review & editing; YVNR & AV: Data compilation, formal analysis, mapping, interpretation, and manuscript preparation; and PJ: Given valuable input and critical feedback to strengthen the manuscript standard.

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